

**PLUG POWER FUEL CELL DEMONSTRATION PROJECT
UNITED STATES MILITARY ACADEMY (USMA)
WEST POINT, NY**

Final Project Description Report

August 2, 2005

Prepared for

**U.S. ARMY CORPS OF ENGINEERS
CONSTRUCTION ENGINEERING RESEARCH LABORATORY (CERL)**
Champaign, Illinois

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In accordance with Contract Number:
DACA42-02-C-0025

Executive Summary

Plug Power Inc. installed and operated three (3) GenSys™ 5CS - 5kW PEM fuel cell systems for one year at the United States Military Academy (USMA) in West Point, NY. The natural gas powered fuel cell systems provided electricity to the residences and incorporated combined heat and power (CHP) capability that allowed waste heat to be recovered from the fuel cell and used to supplement the existing domestic hot water and space heating systems. Additionally, the fuel cell systems included standby capability that allowed the units to operate during periods of electric utility grid (Grid) outage.

The USMA is the home and training ground of the future leaders of the U.S. Army. Plug Power and USMA personnel identified three (3) residential sites within the campus for the fuel cell installations. The locations were selected utilizing criteria based on location, environmental impact, security, staffing, and access. The USMA complex is supplied electricity from Orange and Rockland Utilities (O&RU) and has a primary metered service classification where only the main feed to the complex is metered. Complete installation cost for the project was \$51,100.

The host site point of contact for the USMA was:

LTC Darrell Massie,
Associate Professor
Department of Civil and Mechanical Engineering
(845) 938-4037

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Combined Heat and Power Fuel Cell System (CHP System) Demonstration at the United States Military Academy, West Point, NY (Middle Atlantic Geographic Region)

2.0 Name, Address and Related Company Information

Plug Power Inc.
968 Albany-Shaker Rd.
Latham, NY 12110

Data Universal Numbering System (DUNS) Number: 159700830
Commercial and Government Entity (CAGE) Code: 2AAT3
Taxpayer Identification Number (TIN): 223672377

Plug Power Inc. (Plug Power) designs, develops and manufactures on-site electric power generation systems utilizing proton exchange membrane (PEM) fuel cells for stationary applications. Plug Power's fuel cell systems will be sold globally through a joint venture with General Electric and through DTE Energy Technologies in a four-state territory, which includes Michigan, Illinois, Ohio and Indiana. The Company's headquarters are located in Latham, N.Y., with offices in Washington, D.C., and The Netherlands.

3.0 Production Capability of the Manufacturer

CHP Systems are manufactured at Plug Power's Latham, New York manufacturing facility. This facility, which opened in February 2000, is comprised of 50,000 square feet of dedicated production and production test facilities. Plug Power employs approximately 100 personnel in its production areas. The production processes are designed around the principles of Lean Manufacturing, and use the Toyota Production System as a model. As such, planning and production is via a "pull system" that is, systems are produced only as orders pull demand for product through the production system. Lead-time for delivery is between eight (8) and twelve (12) weeks for large orders, smaller orders (less than ten) can be fulfilled immediately. Current production capability allows for the manufacture of approximately five (5) units per week with the ability to significantly increase this rate.

4.0 Principal Investigator(s)

Mr. Scott Wilshire
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Plug Power, Inc.
P: (518) 782-7700 x1338
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5.0 Authorized Negotiator(s)

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Mr. Gerard Conway
Director of Government Relations
Plug Power, Inc.
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6.0 Past Relevant Performance Information

Long Island Power Authority
333 Earle Ovington Blvd
Suite 403
Uniondale, NY 11553
POC: Mr. Daniel Zaweski, (516) 719-9886
Project Title: Fuel Cell Demonstration Program
Contract Identification Number: N/A

- Contract Award Date: May 15, 2001
- Contract Amount: \$7M
- Contract Award Date: February 22, 2002
- Contract Amount: \$3.6M

New York State Energy Research and Development Authority
17 Columbia Circle
Albany, NY 12203-6399
POC: Mr. James Foster, (518) 862-1090 x3376
Project Title: Fuel Cell Demonstration Project
Contract Identification Number: No. 4870 - ERTER - BA - 99

- Contract Award Date: January 25, 1999
- Contract Amount: \$3M

National Fuel Gas Corporation
10 Lafayette Square
Buffalo, NY 14203
POC: Mr. Rob Eck, (716) 857-7711
Project Title: Residential Fuel Cell Demonstration Project
Contract Identification Number: N/A

- Contract Award Date: February, 2002
- Contract Amount: \$200K

7.0 Host Facility Information

The United States Military Academy (USMA) in West Point, NY is the home and training ground of the future leaders of the U.S. Army. Since its founding two centuries ago, the Military Academy has accomplished its mission by developing cadets in four critical areas: intellectual, physical, military, and moral-ethical - a four-year process called the "West Point Experience." Specific developmental goals are addressed through several fully coordinated and integrated programs.

Ever mindful of its rich heritage, West Point continues to prepare its graduates to serve as commissioned leaders of character in America's 21st Century Army. 2002 marks the bicentennial of this American "national treasure." Guided by its timeless motto, Duty, Honor, Country, the Military Academy is poised confidently to provide the Army and the Nation with its third century of service.

The USMA complex is supplied electricity from Orange and Rockland Utilities (O&RU) and has a primary metered service classification where only the main feed to the complex is metered.



8.0 Fuel Cell Installation

Plug Power and USMA personnel identified three (3) residential sites within the campus for the fuel cell installation:

- 221A Lee Rd, Lee Housing Area – COL Boettner
- 290B Lee Rd, Lee Housing Area – LTC Massie
- 76A Schofield Place, Lusk housing area – COL Nygren

Table 1 shows the average electrical demand for each site (information provided by USMA).

Fuel Cell Site	Number of Systems	Operating Profile Steady State	Monthly Average Production	* Estimated Monthly Average - Demand	Expected % of Demand Provided
		kW	Kilowatt-hours	Kilowatt-hours	
Housing Unit 1	1	2.5	1800	1219	148%
Housing Unit 2	1	2.5	1800	1219	148%
Housing Unit 3	1	2.5	1800	1219	148%

Table1: West Point Installation sites

* Demand at each Fuel Cell site includes 1 residence and 1 mechanical room

Each site had one (1) fuel cell system:

- The fuel cell systems were configured for standby power generation mode. In standby mode, the systems would continue to supply power to the residences in the event of a power (grid) outage. Each tenant was allowed to select five circuits in their existing electrical panel that they would like to keep energized. These circuits were switched over to a new critical load panel that was installed at each site.
- Thermally, the fuel cells were integrated to support/supplement the existing domestic and hot water heating needs of the sites. BTU meters were installed at each site in order to measure the amount of heat transferred from the fuel cell into the site host's hot water system. In addition, space-heating elements (baseboard heat, forced hot-air unit) were installed and monitored in order to study the effectiveness and efficiency of the CHP loop for this type of application.

Plug Power retained Industrial Process Design, Inc. (IPDI) for their engineering and general contracting services during the installation phase of this project. The scope of work included development of an engineering package containing all details of site construction, foundation preparation, installation of the natural gas, water and CHP systems, electrical interconnection and all miscellaneous piping, conduit, wiring and construction coordination activities. All work was performed under a lump-sum contract for a total of \$51,100 or approximately \$17,000 per system. IPDI held two sub-contracts for completion of the electrical and mechanical work. An installation timeline showing major milestones can be found in Table 2.

Table 2: Installation Timeline

Completion date	Task
November 27, 2002	Contract signed by all parties
November 28, 2002	Start site engineering
December 13, 2002	Foundation preparation for fuel cell placement
December 16, 2002	System delivery and rigging
January 4, 2003	Engineering package completed and approved by Plug Power and USMA
March 3, 2003	Start electrical construction

March 5, 2003	Start mechanical construction
March 18, 2003	Finish mechanical construction
March 21, 2003	Finish electrical construction
April 24, 2003	Preventative maintenance on systems to address potential issues from extended cold weather storage
April 25, 2003	Installation of protective, wooden pipe covers
April 25, 2003	Initial system start-ups
May 2, 2003	Commissioning of fuel cell systems

During the site selection process (Spring 2002), the primary focus was the location of utility connections and logistics for shipping, rigging and construction within a residential area. A typical utility penetration is shown in Figure 1. Figure 2 illustrates the difficulty that can arise when working around existing landscaping.



Figure 1



Figure 2

The systems were delivered to West Point in December 2002 and were stored outdoors, at their respective sites, until construction was finished in February of 2003.

Completed Site Photographs

Boettner residence (221A Lee Rd.)



Typical Mechanical room



Massie residence (290B Lee Rd.)



Nygren residence (76A Schofield Pl.)



9.0 Electrical System

The GenSys™ 5CS PEM fuel cell system has a 120 VAC @ 60 Hz output. The fuel cell system is rated for 5 kW (5 kVA) maximum, and 10 kVA for 5 seconds of overload conditions. The minimum set point is 2.5 kW (2.5 kVA). In standby mode, the system will follow any 0 to 5 kW load at the critical load panel (see mode descriptions below). The electrical output is single-phase line to neutral with a separate ground and the system has a unity power factor, $pf = 1.0$.

The GenSys™ 5CS is considered a utility interactive current source that automatically synchronizes itself to the grid's voltage and frequency. The inverter has a microprocessor-based controller that senses the grid, feeds the signal back and outputs the matching, synchronized signal. The inverter was designed to automatically isolate itself if an over/under voltage or frequency is experienced. Furthermore, the inverter has a circuit breaker that will trip if over current is experienced from the grid. Islanding protection is certified by Underwriters Laboratories to the UL 1741 standard.

An automatic transfer switch is internal to the inverter and a manual disconnect switch is mounted near the system. Other than the electrical output connections, the customer is not required to provide auxiliary power to the unit. Internal batteries and the grid provide all the power necessary for start-ups, transients, shutdowns, etc. The system can start up independent of grid status but will not export to the grid unless normal grid conditions exist

Mode Description - The GenSys™ 5CS:

- Grid parallel: This is the standard operating mode of the fuel cell system. The system generates power at a fixed set point and exports it to the facility. Unused power is sent to the grid or, if more power is needed, it will be taken from the grid. This is accomplished by back-feeding a 50-amp breaker in an existing electrical panel. In this type of interconnection, if the grid fails, the system will safely isolate itself from the grid. Upon return of the grid, the system will synchronize itself and reconnect with the grid.
- Standby: If this feature is used, the fuel cell will continue to provide electricity to critical loads in the event of a grid failure. A separate critical load panel must be installed to use this feature. Up to 5kW of critical circuits are wired in from the existing electrical panel and will remain powered if there is a power outage. Upon return of the grid, the system will synchronize itself and switch back to a grid parallel mode. This feature was successfully demonstrated during the major northeast blackout in August 2003. During that prolonged grid outage, the residences fed by fuel cells remained powered while the rest of the West Point facility was left in the dark.

The standby function is an important system characteristic that many customers and site hosts find attractive. For this installation the basement walls were partially exposed in the mechanical rooms. This enabled easy installation of the Critical Load Panel (CLP). With the exception of 240volt loads, all circuits on the CLP were kept energized during grid outages.

In addition, Plug Power offers a Customer Interface Panel (CIP). The CIP gives the end user the ability to change power setpoints and shut the system down. CIP panels were installed at each of the sites and used periodically throughout the demonstration.

10.0 Thermal Recovery System

The CHP heat recovery loop is an external system that circulates a heat transfer fluid (typically propylene-glycol/water mixture) from the fuel cell to the point of use (baseboard heat, hot water tank, etc.). The fuel cell system is designed to operate normally if there is no CHP loop installed or if the customer demand at any time is zero. The excess heat generated by the fuel cell will simply be discharged through the existing radiator.

The external CHP loop should be designed to meet the following specifications:

- Flow: 0-10 gpm (1-2 gpm will maximize heat reclamation from the fuel cell)
- Pressure: ≤ 30 psig
- Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140°F
- Available heat:
 - 11,200 BTU/hr @ 2.5kWe
 - 21,900 BTU/hr @ 4.0kWe
 - 27,000 BTU/hr @ 5.0kWe

The West Point installation utilized the thermal output of the GenSys™ 5CS system to supplement the existing gas fired hot water tank in the mechanical room. See Appendix D for details. The existing hot water tank serves as the sole source of hot, potable water for the residents. The

CHP usage pattern can be best described as a batch heating process followed by a maintenance cycle. As the residents consumed hot water, the CHP loop would act to bring the fresh water in the tank up to temperature (~135 °F). When the tank temperature setpoint was reached, the CHP loop would maintain the temperature while it waited for another period of water usage. At 290B Lee rd. (Massie residence), a forced air heat exchanger (HX) was installed in addition to supplementing the hot water tank. This HX served to supplement the heat for the basement area. A BTU meter was installed at all three sites to monitor the thermal performance of the CHP loop.

A new CHP configuration was tried for the first time at the West Point facility. Plug Power tied the CHP loop directly into the potable water system for the residences. Typically, a heat exchanger or additional water tank and pump would be installed to provide two layers of separation/protection between potable water and propylene glycol mixtures. This extra equipment drove cost up and overall efficiency down. Plug Power was able to avoid the added cost/complexity of this equipment because of a new declaration in the Plumbing Code of New York State – 2002. The Plumbing Code states:

Chapter P2 - Definitions

ESSENTIALLY NONTOXIC TRANSFER FLUIDS. Fluids having a Gosselin rating of 1, **including propylene glycol**; mineral oil; polydimethylsiloxane; hydrochlorofluorocarbon, chlorofluorocarbon and hydrofluorocarbon refrigerants; and FDA-approved boiler water additives for steam boilers.

Chapter P6 – Water Supply and Distribution

§P608 – Protection of Potable Water Supply

§P608.16.3 Heat exchangers. Heat exchangers utilizing an essentially toxic transfer fluid shall be separated from the potable water by double-wall construction. An air gap open to the atmosphere shall be provided between the two walls. **Heat exchangers utilizing an essentially nontoxic transfer fluid shall be permitted to be of single-wall construction.**

These declarations, along with approval by West Point, enabled Plug Power to connect the CHP loop directly to the potable water system in the mechanical room. The result was a cheaper, more efficient system. However, there were a number of lessons learned that are directly transferable to future projects.

- Plumbing compatibility – the introduction of potable water into the fuel cell system required some changes to the installation and to the fuel cell itself. New plumbing internal and external to the fuel cell was required to meet FDA compatibility and pressure requirements for potable water applications.
- Freezing issues – typically, a propylene glycol and water mixture is used as the CHP loop heat transfer fluid. By introducing pure water into the fuel cell, all external piping from the building to the fuel cell required electrical heat tracing.
- BTU meter and deposit buildup – The potable water installation resulted in an open loop system where fresh water, complete with minerals and deposit forming material, was constantly circulated through the CHP plumbing. In addition, a pre-existing sediment layer on the bottom of the hot water tank was disrupted and circulated through the piping system. The sediment was eventually cleaned out after a series of system flushes. The constant introduction of fresh water however, continued to form deposits on the turbine flow meter of the BTU meter installed at all three residences. The result was that the meter would seize up and cease functioning. A few months into the project, Plug Power noticed for the first time that the meter

had stopped registering. A close examination of the turbine meter showed that there was a significant amount of buildup on the meter and it was returned to the manufacturer for cleaning and remanufacturing. The manufacturer replaced the wetted components with titanium parts that were supposed to inhibit the buildup. The meter was reinstalled and failed about a month later. The time lag between failure and repair was on the order of 2 months. For a 1-year demonstration, that is a significant period of time. In all, the meters failed many times. Neither Plug Power nor the manufacturer anticipated this failure mode. Consideration has been given to potential future installations where a potable-water CHP system would be desired. Relocation of the BTU meter to a different point of the loop, water softening, and comprehensive water filtration among other measures will be addressed.

- Thermal Efficiency- For the 5 months where complete thermal data exists there was fairly low demand for CHP heat. This is typical for a domestic water application where heating is usually done in a batch mode and the majority of the time is spent maintaining the tank at temperature. The amount of heat reclamation by the CHP system is directly related to the hot water usage of the residents. During the mid-day and night hours, heat recovery was lowest. These three sites had the added benefit of having baseboard heaters installed that were feed by the CHP loop. Alternatively, a CHP application with a large heat demand (like a swimming pool) would see much higher efficiencies.

11.0 Data Acquisition System

The GenSys™ 5CS is designed to automatically send operational data (sampled every 10 minutes) once per day, via modem/dial-up connection, to Plug Power. Once at Plug Power, the data is entered into the fleet Quality Tracking Management System (QTMS) database. Furthermore, during every system shutdown, the unit automatically reports to Plug Power its status, error logs and high-speed data. The high-speed data is a packet of data-points taken at a much higher resolution (every second for the last 10 minutes). This information is used to track preventative maintenance items, troubleshoot failures, and dispatch field service technicians. Complete system operational data can also be downloaded directly from the machine by a trained service technician with a laptop and RS232 connection cable.

12.0 Fuel Supply System

The GenSys™ 5CS fuel cell system is fueled by natural gas. The service connections at the residential sites were made downstream of the existing gas meter.

The GenSys™ 5CS natural gas requirements are:

- Constituency must be >90% methane.
- Sulfur content no greater than 15 ppm on a yearly average basis.
- Supply pressure: 4" – 11" water column.
- Maximum flow rate: 105,000 BTU/hr (~ 70 slm during startups).
- Nominal flow rate: 72,700 BTU/hr (~ 50 slm at 5kW setpoint).

13.0 Program Costs

An economic breakdown of the project and a comparison to the initial economic analysis provides context to the program. Table 3 details the project cost breakdown. Appendix A provides the data for gas consumption and CHP production and Appendix E is the initial economic analysis performed at the beginning of the project.

As discussed in Section 10.0 – Thermal Recovery System, the thermal data from this project is incomplete. However, an estimate of thermal performance can be generated from the five months where complete data exists. The following is a list of the systems and months when complete thermal data was collected:

- B180 – November, 2003
- B180 – December 2003
- B180 - January, 2004
- B178 – November, 2003
- B178 – December, 2003

Extrapolation of the data above and multiplication of the result by the availability of the fleet (96%) produces an estimated 1,830 Therms of CHP heat reclamation for all three sites.

Table 3: Economic Analysis

Final Cost Breakdown

	Qty	Total Cost
System Purchase Cost	3	\$181,500.00
Warranty	3	\$90,000.00
Installation Cost (incl. performance monitoring equip)		\$51,100.00
Travel		\$1,000.00
Decommissioning		\$4,600.00
Add'l Thermal Monitoring Equip		\$24,250.00
Total Program Cost		\$352,450.00
Total Contract Award		\$347,942.00
Total Project Overrun (covered by Plug Power)		\$4,508.00

Actual Avoided Cost @ West Point

	Qty	Price*
Power Generated (kWhe)	62,393	\$4,991
Heat Reclaimed (Therms)	1,893	\$1,371
Fuel Usage (Therms)	8,870	
Fuel Rate (\$/Therm)	\$0.72	
Fuel Cost (\$)		\$6,422
Avoided Cost (\$)		-\$60
* Price of heat and power if purchased from the utility. (NG = \$.724/Therm, Electric = \$0.08/kWh)		

Comparisson - Avoided Cost using NYS average gas and electric rates

	Qty	Price*
Power Generated (kWhe)	62,393	\$8,735
Heat Reclaimed (Therms)	1,893	\$2,196
Avoided Cost (\$)		\$4,509
* Price of heat and power if purchased from the utility. (NG = \$1.16/Therm, Electric = \$0.14/kWh)		

Cost of Energy @ West Point

	Electricity \$/kWe	Heat \$/kWt	CHP \$/ (kWe+kWt)
Fuel cost only	\$0.10	\$0.12	\$0.05
Fuel + equipment/warranty cost	\$4.45	\$5.01	\$2.36
Fuel + equipment/warranty + installation cost	\$5.27	\$5.93	\$2.79
Total project cost	\$5.65	\$6.35	\$2.99

Notes on Table 3:

- The final cost breakdown takes into consideration the installation of the additional Thermal Monitoring for COL Massie's site.
- The avoided cost is the difference between the amount of money that would have been paid if the power and heat were purchased from the utility minus the cost of the natural gas used. The avoided cost of \$-60.00 is low due to the low cost of electricity and fuel at the West Point facility. When compared to the NYS averages, the avoided cost is significantly more favorable.
- The cost of energy illustrates the impact of unit and installation cost on the effective rate of energy. With the total project cost factored in, a CHP rate of \$2.99 / kW is realized. This is roughly a factor of 40 from where a commercial product needs to be in order to compete with the grid.

14.0 Milestones/Improvements

The demonstration at the West Point Military Academy resulted in some significant milestones and product/process improvements. The most noteworthy of which are described below:

- Availability - The three-system fleet finished the 1-year demonstration with an availability of over 96%. One of the systems had final availability over 97.5%. These are significant improvements over previous demonstrations. A system that is 96% available is down for only 14.6 days per year. This is a significant achievement considering the distance of the USMA from Plug Power, Latham (2 ½ hours).
- Fuel Cell Stack Life - A major increase in stack life was experienced during this demonstration. Additional testing is underway and details will be provided in an addendum to this report.
- CHP Design - This was the first Plug Power site where the CHP loop was used to directly heat potable/drinking water.
- Software – Software improvements enabled the systems to run longer time between failures and automated many processes that previously required manual intervention or a visit to the site. For example, addition of an auto-restart function and the ability for Plug Power to call into a system to check status. In earlier versions of software, communication was one-way only – the system would transmit data to Plug Power.
- Standby Capability – The GenSys™ 5CS is able to supply power during grid failures. During the major, northeast black-out in August 2003, the fuel cell systems continued to operate in standby mode and supply power and domestic hot water to the residences.
- Notification - Software was developed and installed on the Technical Support Line server to notify Plug Power personnel when a system had shut down via text messaging through a cell phone.

15.0 Decommissioning/Removal/Site Restoration

A no-cost program extension was granted to Plug Power to allow operation of the fuel cell systems until July 31, 2004. Plug Power requested the additional run-time in order to perform additional stack life testing. Plug Power de-commissioned the remaining two units after their demonstration period ended on 5/2/04. All three systems will be removed and the sites restored

no later than August 31, 2004. The sites will be restored to their original condition once the systems have been removed.

An addendum to the final report will be submitted to document the continued operation of the units and to report on final site decommissioning activities.

16.0 Additional Research/Analysis

Pursuant to contract modification # P-00002 (dated 7/23/03), funds totaling \$24,250 were added to the contract for LTC Massie to install additional thermal monitoring equipment at the 290B Lee Rd. site. This data was recorded via a data acquisition system. This data will be discussed in more detail within the addendum to this report.

17.0 Conclusions/Summary

In conclusion, the FY02 PEM fuel cell demonstration at the West Point Military Academy was a tremendous success. New availability benchmarks were set, increased system functionality was field-tested, product and process improvements were initiated and field support tools and techniques were implemented. The benefits of fuel cell technology and distributed power generation were evident during the major blackout that hit the northeast in August 2003. The three housing units had backup power through the utility grid outage. This is a powerful symbol of the potential that this technology has to change the way the world generates, transmits and utilizes power.

Some of the key take-away points from this project are:

- Freeze protection and cold weather issues – It is intuitively obvious that an outdoor piece of equipment that uses water must have safeguards against freezing. Plug Power was able to use the lessons learned from this project to improve the system design, field-support cold weather service techniques and internal test and verification procedures. All of these improvements will lessen the chance of freeze damage and allow the user to respond if in fact it does happen in the future. This type of learning cannot happen in the laboratory.
- Site Installation issues – Heavy ice build-up and similar weather related phenomena must be considered when selecting a site. Thought must be given to the “what if....?” scenarios such as heavy rain, severe snowfall, water run-off paths, etc. Again, these are lessons only learned in the field and have a direct, positive impact not only during the installation phase, but long-term during operation.
- Potable water CHP installations – Validation of the potable water installation was an important step in the development of a CHP application profile. The ability to adapt to specific site conditions and integrate with different facility systems is critical to the future of fuel cell technology. The compatibility of equipment within this environment is important. This program suffered from a poor understanding of the tenacious nature of potable water and its desire to leave mineral deposits and calcium build-up on everything it touches. Future installations will avoid a repeat of this experience and new locations/modifications will be made to the BTU monitoring scheme used.

- Cost reduction – The typical GenSys™ 5CS fuel cell installation currently runs anywhere from \$8000 upwards of \$30,000 per system. There are always extenuating circumstances, but the fact remains – this is the real world and the ideal site does not exist. The West Point Military Academy was fortunate to benefit from economy of scale and new interpretations of the NYS building codes that allow the use of potable water within the CHP loop. This interpretation allowed Plug Power to save approximately \$1500 in auxiliary equipment per system and realize an installation cost of roughly \$17000 each. This is still 5-6 times too expensive. Close interaction between the Customer, Field Support Group and Product Engineering is vital to capture and incorporate the lessons learned from the field into future generation products.

Long term, the only realistic way to reach a reasonably priced installation is through elimination of system requirements. For example:

1. An indoor unit eliminates or reduces the need for:
 - a. Foundation preparation
 - b. Underground piping or fabrication of protective systems
 - c. Weatherproof support equipment (i.e. electrical enclosures)
 - d. Freeze issues
 - e. CHP loop equipment
 - f. Building penetrations
 - g. Etc.
2. A water independent system will eliminate the following scope of work:
 - a. A water sample must be taken and sent to a lab for analysis.
 - b. A pretreatment solution (if necessary) must be designed, procured and installed. Typically a softener or pre-filter package is required.
 - c. Potable water (not always accessible) must be plumbed to the area.
 - d. The DI panel must be mounted.
 - e. A drain must be located (or installed) for the DI box.
 - f. The multi-tube heat trace bundle must be run in a conduit with electrical heat trace.
 - g. Terminations must be made on each end.
 - h. The solenoid wire must be run inside a separate conduit with the communications wiring.
 - i. The customer must use approximately 220 gallons per day of city water at 5kW and send 154 of that to the drain (not popular in drought areas).
 - j. Etc.

Appendix

- A. Monthly Performance Data
- B. Maintenance Logs
- C. Site Installation Drawing

- D. CHP Installation Drawing
- E. Initial Economic Analysis

Appendix A

Monthly Performance Data

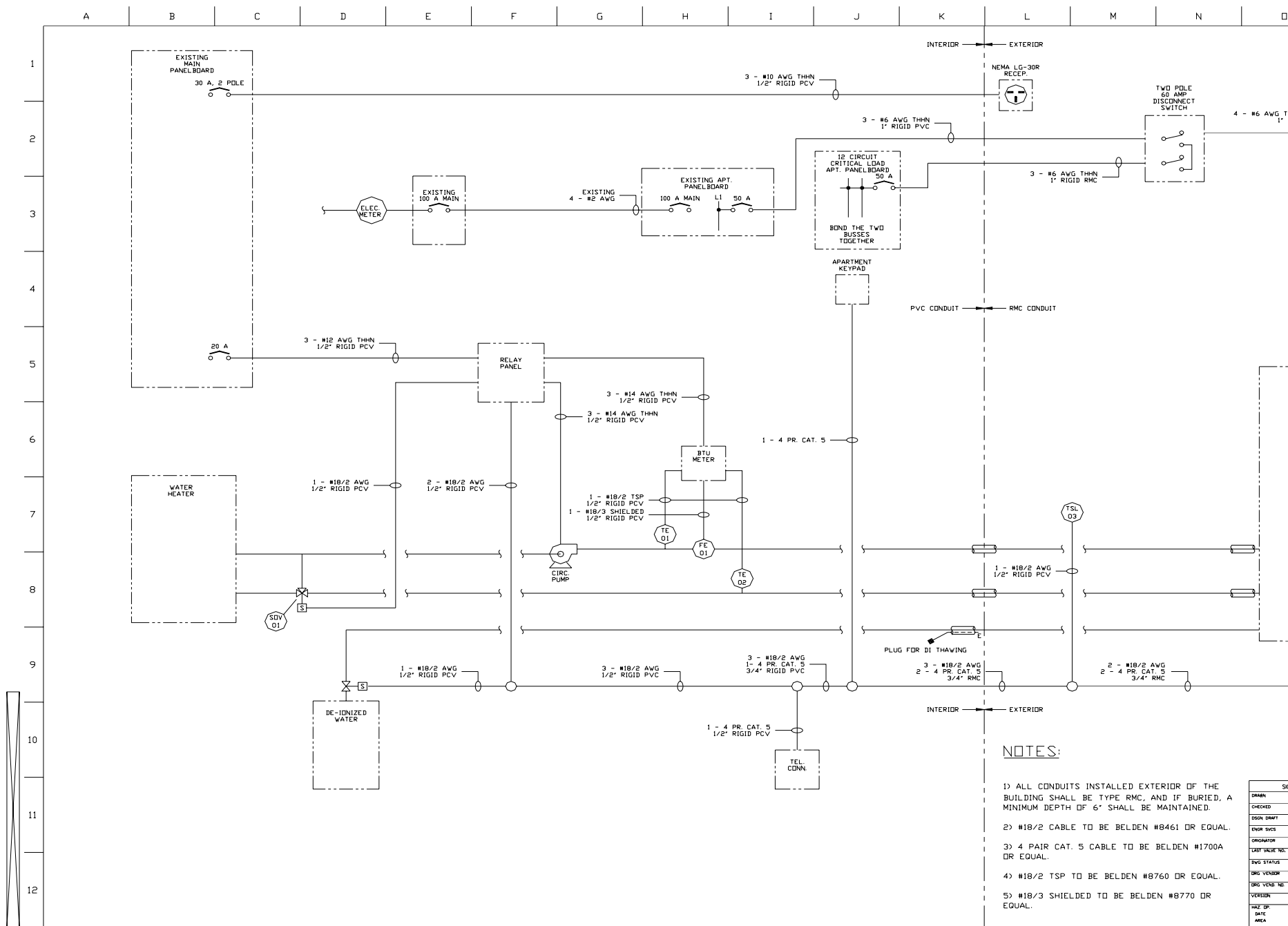
Appendix B

Maintenance Logs

Plug Power Proprietary and Confidential Information

Appendix C

Site Installation Drawing



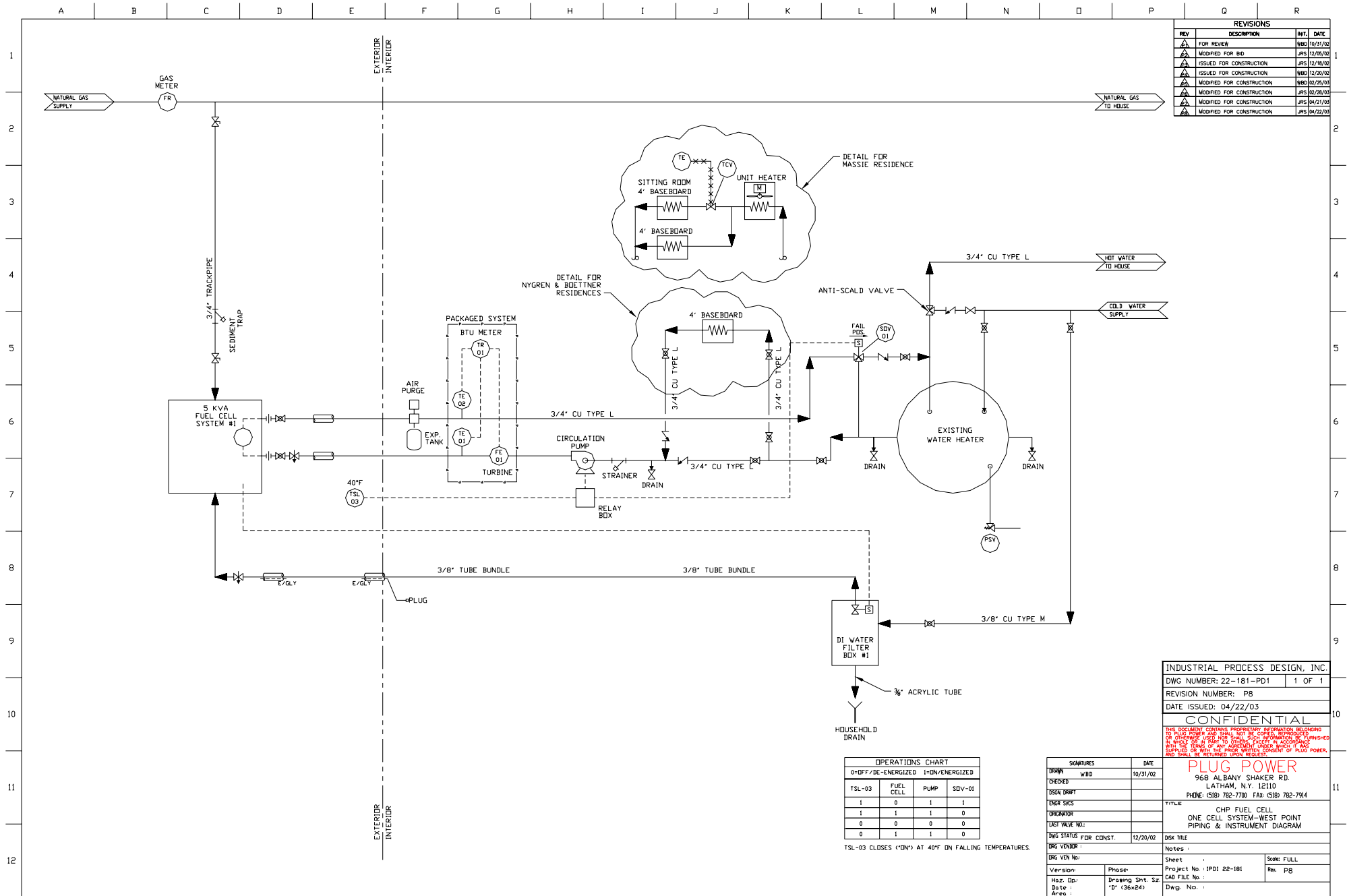
NOTES:

- 1) ALL CONDUITS INSTALLED EXTERIOR OF THE BUILDING SHALL BE TYPE RMC, AND IF BURIED, A MINIMUM DEPTH OF 6" SHALL BE MAINTAINED.
- 2) #18/2 CABLE TO BE BELDEN #8461 OR EQUAL.
- 3) 4 PAIR CAT. 5 CABLE TO BE BELDEN #1700A OR EQUAL.
- 4) #18/2 TSP TO BE BELDEN #8760 OR EQUAL.
- 5) #18/3 SHIELDED TO BE BELDEN #8770 OR EQUAL.

SK	
DRAWN	
CHECKED	
DESIGN	
ENGR SVCS	
ORIGINATOR	
LAST VALUE NO.	
ENG STATUS	
ENG VENDOR	
ENG VENDOR NO.	
VERSION	
HAZ OP	
DATE	
AREA	

Appendix D

CHP Installation Drawing



Appendix E

Initial Economic Analysis

PROGRAM INITIAL ECONOMIC ANALYSIS

This program consists of the planning, installation, and operation of 3 Plug Power fuel cell systems at various locations supporting operations at the United States Military Academy (USMA) – West Point, NY.

The USMA Department of Housing and Public Works (DHPW) provided the utility rates below as averages for FY2002.

- Electrical = \$0.08/kW-hr
- Natural Gas = \$7.24/decatherm

The system gas usage rate is based upon the nominal Plug Power Lower Heating Value for natural gas of 804 kJ/mol and an average beginning of life (BOL) electrical efficiency of 24.8%. This efficiency is calculated using a weighted average of the system efficiencies at the different set points.

- System natural gas usage rate = 0.138 therm/kW-hr

The program run hours is based on 3 systems operating with a total availability of 90% for the one-year life of the program:

- Program run hours = 24 hrs X 365 days X 0.90 X 3 = 23,652 hrs.

The program number of kilowatt-hours (electrical) produced is based on a system power set point of 2.5 kW for the program run hours above:

- Program kW-hrs_e = 2.5 kW X 23,652 hrs. = 59,130 kW-hrs_e

The program number of therms claimed by the customer is based on a system power set point of 2.5 kW for the program run hours above and an overall system efficiency of 50%. Since overall efficiency is based on utilizing the “waste” heat from the fuel cell, the therms claimed by the customer will vary depending on hot water demand:

- Program therms = 2.5 kW / 0.248 X [0.5 – 0.248] X 23,652 hrs X 0.03412 therms/kW-hr = 2,050.1 therms

The program number of therms of natural gas consumed by the fuel cells is based on the usage rate multiplied by the number of program kW-hrs above:

- Program therms consumed = 59,130 kW-hrs X 0.138 therm/kW-hr = 8,159.9 therms

The program total cost of natural gas is based on the number of therms consumed multiplied by the cost per therm:

- NG cost = 8,159.9 therms X \$0.724/therm = \$5,907.77

The equivalent cost of the fuel cell electricity and heat if purchased from Niagara Mohawk is based on the number of kilowatt-hours and therms produced by the systems multiplied by Niagara Mohawk's rate:

- Electrical cost = $59,130 \text{ kW-hrs}_e \times \$0.08/\text{kW-hr} = \$4,730.40$
- Thermal cost = $2,050.1 \text{ Therms} \times \$0.724/\text{therm} = \$1,484.27$

The projected total energy savings for the program by using system-generated electricity and heat instead of purchasing it from Niagara Mohawk is:

- Avoided cost = $\$4,730.40 + \$1,484.27 - \$5,907.77 = \mathbf{\$306.90}$
- Avoided cost per residence = $\$306.90 / 3 = \102.30

The USMA benefits from unusually low electric and natural gas rates when compared to the average for New York State. The state averages for 2001-2002 were approximately \$0.14/kWh electric and \$1.16/Therm natural gas. The chart below shows the effect of various electric rates when compared to a fixed gas rate. In this example, you can see that with the USMA gas rate and the NYS average electric rate of \$0.14/kWh the avoided cost for the demonstration would be roughly \$3,800 (more than a factor of ten higher). Also evident is the fact that the same demonstration at a more conventional residence (non-military facility) with the state average rates would realize cost-savings of near \$1,250 or four times what is seen at the USMA